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13. ABSTRACT *(Maximum 200 words)*

The P.I. spent the summer at the Naval Surface Warfare Center (NSWC) in Dahlgren, VA, working, on the project and providing general technical assistance and education to NSWC personnel. Productive collaboration included: development of Matlab demonstration suite (with Ron Gross), optimizing RF absorption characteristics of multilayer rubber surfaces (with Jack Shuler), and wavelet theory (with Addison Jump).

Ph.D. student Steven Moore was self supporting for 1999; the grant instead supported two Masters' students (Alan Calder and Kevin Conrad) who did supporting software development.

Research accomplishments include: implementation of simulated annealing algorithm; implementation of 1-D and 2-D Discrete Wavelet Transform; parameterization of various wavelet spaces (orthonormal wavelets, synnetric complex orthonormal wavelets, symmetric biorthogonal wavelets of odd and even lengths, and symmetric biorthogonal wavelets of odd and even lengths having specified order of regularity); development of wavelet demonstration software suite with Ron Gross (NSWC); presentation of course "Wavelets and Filter Banks" to NSWC personnel; application of simulated annealing to oprimize RF absorption characteristics of multilayer surfaces; generalization of wavelet transform to M-band wavelets; algorithm to generate a wavelet filter bank using any filter whatsoever as the analysis filter; implementation of an algorithm to parameterize all M-band paraunitary filter banks.

14. SUBJECT TERMS
Target Recognition; Wavelets; Filter Banks; Stochastic optimization; Simulated Annealing; Discrete Transforms

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Annual Progress Report on ONR Grant N000149910091

Title: Wavelet-Based Feature Extraction for Target Recognition and Minefield Detection

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I Summary

This report covers progress made during the first year of the project (December 1, 1998 to November 30, 1999). Ph.D. student Steven Moore is working on this project, but because he chose to be self-supporting for Fall 1998, the grant has instead supported the work of two Masters' students who have done supporting software development. Steven Moore is becoming increasingly familiar with the literature on wavelet theory and shows great potential for success on this project and in his dissertation.

The P.I. spent the summer at the Naval Surface Warfare Center in Dahlgren, VA, working on the project and also providing general technical assistance and education to NSWC personnel. The collaboration with NSWC personnel has been particularly productive, both in regard to the work on this project and also to work in other areas of interest to the Navy. In particular, the work with Ron Gross on the development of a Matlab demonstration suite, with Jack Shuler and Ron Tiedge on optimizing RF absorption characteristics of multilayer rubber surfaces, and with Addison Jump on wavelet theory, deserve mention. Details are given in section II.

II List of Research Accomplishments:

The following work described in the proposal has been completed:

Task 1

1. Implementation of the basic simulated annealing algorithm in Matlab
2. Implementation of the basic simulated annealing algorithm in C
3. Implementation of the Discrete Wavelet Transform in one and two dimensions in Matlab.
4. Implementation of the Discrete Wavelet Transform in one and two dimensions in C.
5. Testing and verification of the above algorithms (1-4). Algorithms 1-4 are general, in that they are able to handle arbitrary image sizes, any number of scales, any wavelet function, and various forms of edge reflection, but still require generalization so that the filter coefficients can be complex.

Task 2

Parameterizations have been found for the following spaces of wavelets:

1. orthonormal wavelets (two parameterizations).
2. symmetric complex orthonormal wavelets
3. symmetric biorthogonal wavelets of odd length
4. symmetric biorthogonal wavelets of even length

Work is ongoing to incorporate into these parameterizations a specified order of wavelet regularity. The P.I. is working with NSWC scientist Dr. Addison Jump to develop a parameterization for orthonormal wavelets of specified regularity.

Other results achieved by the P.I. in addition to work explicitly described in the research proposal are:

1. With the assistance of Ron Gross of NSWC, the P.I. is developing (in Matlab) a software suite to be used to demonstrate the algorithms that will be produced during the research on this project. It currently contains about 5 demonstrations, including the one- and two-dimensional wavelet transforms. This demonstration suite will be continually extended and enhanced as more algorithms are developed.
2. Presentation of an intensive two-day introductory course entitled "Wavelets and Filter Banks" that was presented on July 23 and 29 to over 30 NSWC personnel. This course

resulted in much favorable feedback and the potential for further collaborative work between the P.I. and NSWC research staff.

3. In collaboration with NSWC scientists Jack Shuler and Ron Tiedge, development of Matlab software to optimize RF absorption characteristics of multilayer rubber surfaces. This optimization is based upon the use of simulated annealing, and makes use of the optimizer developed as item (1) under "Task 1" above.
4. Derivation of an algorithm to generate a two-channel perfect-reconstruction filter bank using as the analysis filter any desired filter whatsoever. The algorithm results in a synthesis filter of any desired order of regularity.
5. Generalization of the one-dimensional wavelet transform algorithm to M-band wavelets.
6. Implementation in Matlab of an algorithm that parameterizes all paraunitary M-band filter coefficients.
7. Implementation in Matlab of an algorithm that, given an admissible lowpass filter for a paraunitary M-band filter bank, generates all other filter coefficients in the filter bank.

III Students:

The following graduate students performed work on this project during the period covered by this report:

1. **Steven Moore**, Ph.D. (Elec. Eng.) student. The project forms the subject of Mr. Moore's Ph.D. research work.
2. **Leroy A. Calder**, M.S.E.E. student. Mr. Calder is developing Matlab software in support of the research work of the PI and the Ph.D. student.
3. **Kevin L. Conrad**, M.S.E.E. student. Mr. Conrad developed wavelet transform software in C++ in support of the work of the Ph.D. student.

Because Mr. Moore chose to be self-supporting during the past year, it was possible to support the two M.S.E.E. students instead.

IV Publication:

B.G. Sherlock and Y.P. Kakad: "Windowed Discrete Cosine Transform for Shifting Data", presented at the 3rd IMACS/IEEE International Multiconference on Circuits,

Systems, Communications and Computers (CSCC'99), Athens, Greece, July 1999.

V Presentation:

Intensive two-day introductory course entitled "Wavelets and Filter Banks", presented on July 23 and 29 to over 30 NSWC personnel at Dahlgren, VA.